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A STUDY ON THE METHODS OF MID-RANGE FORECAST
FOR "PLUM RAINS"

Forecasting Group, Shanghai Meteorological Bureau

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A STUDY ON THE METHODS OF MID-RANGE FORECASTS FOR "PLUM RAINS"

Forecasting Group, Shanghai Meteorological Bureau

An investigation was made for the mid-range forecast of the heavy to torrential rain at the beginning and during the period of the "plum rains" by using synoptic circulation patterns and numerical statistics. It was found that the beginning of the rainy season is closely related with the seasonal northward displacement of the ridge line of the western North Pacific sub-tropical high between 125°-140° East at 500 mb. The plum rains occur when the 500 mb ridge line is generally stable between 19°-24° North and when the sub-tropical high ridge line basically extends to 26° N or more.

The forecast of early plum rains should emphasize the movement and variation of the subtropical high while forecasts of normal period or late plum rains should emphasize adjustments and movements of westerly short-wave troughs and ridges.

It should be noted that the time of the occurrence of the heavy to torrential rain synoptic process during the plum rainy season in Shanghai is related to the region in which the interaction between the cold and warm air masses takes place, the characteristics of variations in their intensities as well as the variations of meteorological parameters at the station.

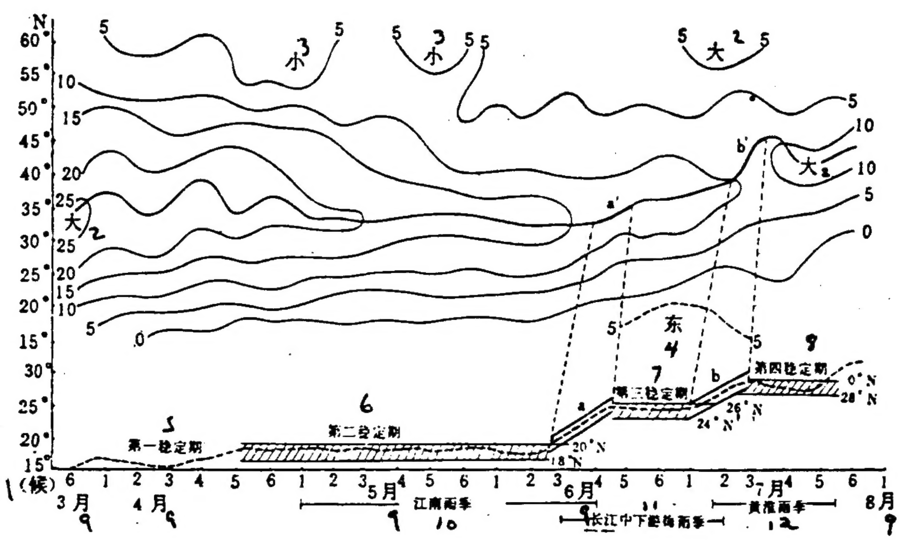
The plum rain season in the lower reaches of the Changjiang is the harvesting period for wheat, oats and barley and the irrigation and seedling planting period for wheat in this region. Therefore, how early or how late these rains begin and end is of great importance to agricultural production in this area. This article uses such methods as synoptic circulation patterns and numerical statistics for an overall study, looking for methods of mid-range

forecasting of the beginning of the "plum rains" and of heavy to torrential rains during the "plum rain" season.

The appearance and duration of the plum rain season is generally related to the circulation of the Euro-Asian air mass, wherein the westerly wind blockage and the movement and location of sub-tropical highs in the Northwest Pacific are especially important. Through surveys, analysis and research, we have discovered that the timing of the coming of the rainy season each year is related to a great degree to the northerly shift of the Northwest Pacific subtropical high ridge line between 125° and 140° East. Figure 1 shows the cross sectional arrangement of the gradual northerly movement of the ridge lines of the sub-tropical highs in the Northwestern Pacific averaged over a number of years (1954 - 1962) of 500mb between 125° and 14-° East and the times of the gradual shift to westerly winds. We can see from the graphs in Figure 1 that the average ridge lines of the sub-tropical highs make two rapid rises in their gradual northerly shift between April and July (sections **a** and **b** in the graph) and that there are four periods of relative stability. The first period of stability is in April. The second is from the end of April to the end of the middle ten days of June during which time the ridge line of the sub-tropical high fluctuates slightly between 18° and 20° North. This coincides with the rainy season in Southern China south of the Changjiang River. The third period of stability is from the end of the middle ten days of June to the first ten days of July during which time the ridge line of the sub-tropical high lies between 24° and 26° North which coincides with the plum rains of area in the lower reaches of the Changjiang River. The fourth period of stability is from the middle ten days until the end of July, during which time the ridge line of the sub-tropical highs fluctuates between 28° and 30° North and which coincides with the rainy season in China's Yellow and Huai river areas. We can also see from this figure that the sub-tropical high ridge line makes two market jumps between the middle of June and the first ten days of July which

coincides with the maximum westerly shift of the winds at 500 mb (upper portion of Figure 1). This common shift in the westerly wind and sub-tropical highs illustrates that there are seasonal changes in the process of a northerly shift of the sub-tropical highs.

Fig. 1. Average shift of 500 mb between 125° and 140° East of Sub-tropical high ridge lines in the Northwest Pacific for the years 1954 to 1962



1. Time. 2. High. 3. Low. 4. East. 5. First period of stability. 6. Second period of stability. 7. Third period of stability. 8. Fourth period of stability. 9. Month of the year. 10. Rainy period in South China. 11. Rainy period in middle and lower reaches of Changjiang. 12. Rainy period in Yellow and Huai river areas.

Note: 1. In the upper portions of this figure, the coarse lines are the location of the maximum westerly wind axis and the fine lines are isotach lines. 2. The dotted line in the lower portion of the graph is the latitude of the gradual northerly shifting sub-tropical high average ridge line. The inclusive lines between line stops are the average beginning and ending dates over the inclusive years of the various rainy seasons. 3. a'-a and b'-b are the corresponding sudden change sectors in the upper and lower portion of the graph.

Figure 1 shows the average situation over a number of years. There are, however, marked differences from year to year in when

the plum rains begin and end and when the sub-tropical highs reach the latitudes mentioned above. We can see from statistical results of data over more than 20 years (Table 1):

Table 1. Average location of sub-tropical high ridge lines 125°-140°E) when rainy season began each year

1 年份	54	55	56	57	58	59	60	61	62	63	64	65
2 入梅期	6.1	6.17	6.5	6.20	6.27	6.28	6.18	6.6	6.71	6.22	6.23	6.25
3 入梅该候副高脊线所在纬度	20.0	23.0	23.5	21.0	23.0	19.0	22.0	21.0	19.5	27.5* 台风影响	24.0	21.0
4 出梅期	8.2	7.8	7.19	7.12	6.29	7.7	6.29	6.16	7.7	7.8	6.28	7.6
5 出梅该候副高脊线所在纬度	35.0	28.0	28.5	27.0	26.0 空梅	22.0	28.5	27.0	27.0	25.5	24.0	26.5
6 出梅次候副高脊线所在纬度	32.0	34.0	28.0	28.5	2.50	26.0* 台风转向	24.5 风台	30.0	26.0	29.0	29.1	28.4

1 年份	66	67	68	69	70	71	72	73	74	75	76	
2 入梅期	6.24	6.24	6.23	6.24	6.18	5.26	6.20	6.16	6.10	6.17	6.16	
3 入梅该候副高脊线所在纬度	22.4	21.8	19.4	20.0	20.4	22.4	19.3	18.6	23.4	24.3	21.2	
4 出梅期	7.12	7.9	7.11	7.16	7.18	6.26	7.3	6.29	7.18	7.16	7.17	
5 出梅该候副高脊线所在纬度	27.7	27.1	24.2	31.0	24.2	24.8	24.7	25.1	25.4	29.2	29.8	
6 出梅次候副高脊线所在纬度	30.0	25.4	28.3	30.3	33.0	28.5	27.7	28.4	26.6	29.2	35.0	

1. Year. 2. Date of start of plum rains. 3. Latitude of sub-tropical high ridge line during five day period of start of plum rains. 4. Date of end of plum rains. 5. Latitude of sub-tropical high ridge line during five day period of end of plum rains. 6. Latitude of sub-tropical high ridge line during five day period following the five day period of the end of plum rains.

During the five day period during which the rainy season begins the average sub-tropical high ridge line between 125° and 140° can basically be stabilized along the strip of latitudes between 19° and 24° (some years are affected by typhoons), and the ridge line can be moved greatly northward temporarily, but are not stable). Furthermore, during the five day when the rainy season concludes or during the following five day period, the sub-tropical high ridge line can move north of 26° North latitude. These statistical results are significant to a certain degree in attempting to determine when the rainy season will begin and end.

1. Mid-range (5-7 days and 2-3 days) forecasting of plum rains - the circulation model method

In order to better recognize the changes in the forms of circulation before the plum rains begin and to combine this with the requirements of production departments, based on the 500 mb and the surface weather maps, we checked the circulation model and forecasting conditions for every year from 1954 to 1964 for thee different forecasts (5-7 days, 2-3 days, and next day), forecasting the beginning of the plum rains according to the following steps:

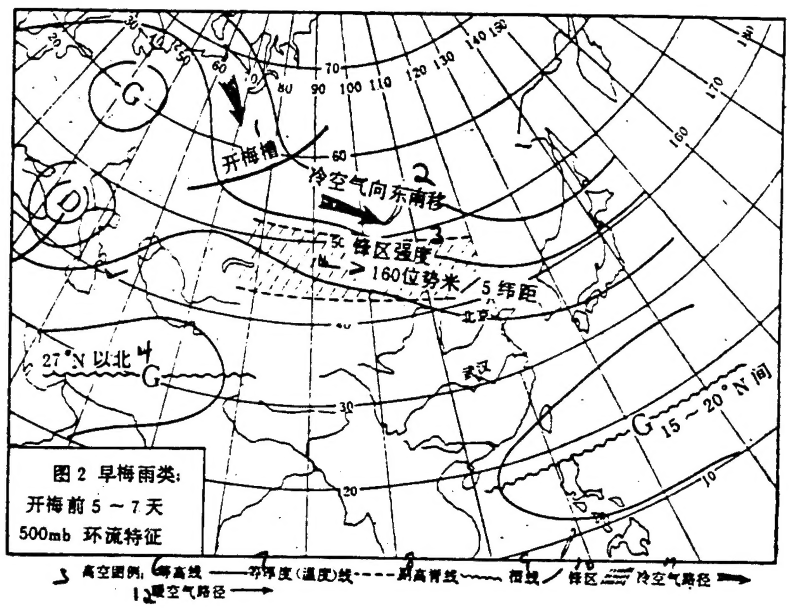
The 500 mb circulation 5-7 days prior to the rainy season and forecasting conditions (divided into two models) → the circulation and forecasting conditions two to three days prior to the beginning of the rainy season (divided into two models) → The 500 mb circulation model and surface conditions 24 hours prior to or the day the rainy season begins (divided into three models).

In this manner, and using the experiences of more than ten years of forecasting operations, the 500 mb circulation form and forecasting conditions prior to the onset on the rainy season can be basically divided into two models which are:

A. The rainy season begins early. Five to seven days prior to the onset of the rainy season (Figure 2) the primary characteristics are a European obstruction and a flat Asian wind. The European circulation form has a developing blocking high pressure in Northern Europe, with a fairly strong swirling pocket of cold air to the south of the blocking high near the Black Sea. At the same time to the southeast of the swirling low there is a southwest or southerly wind greater than 20 meters per second. This means that the high pressure system over Western Qinghai-Tibetan plateau and Iran is somewhat to the north. In the Asian region between 40° and 55° North and west of 120° East there is a fairly strong westerly flat flow of air. The intensity of the frontal zone is 160° geopotential meters for every five latitude

distances. The cold air in the higher latitudes follows the eastern side of the European blocking high and moves to the south and southeast, entering into the northeast portion of the high plateaus. At this time the ridge line of the sub-tropical high in the Western Pacific lies along the coast between 15° and 20° North.

Fig. 2. Model for when the rainy season comes early, 500 mb circulation 5-7 days before onset of plum rains

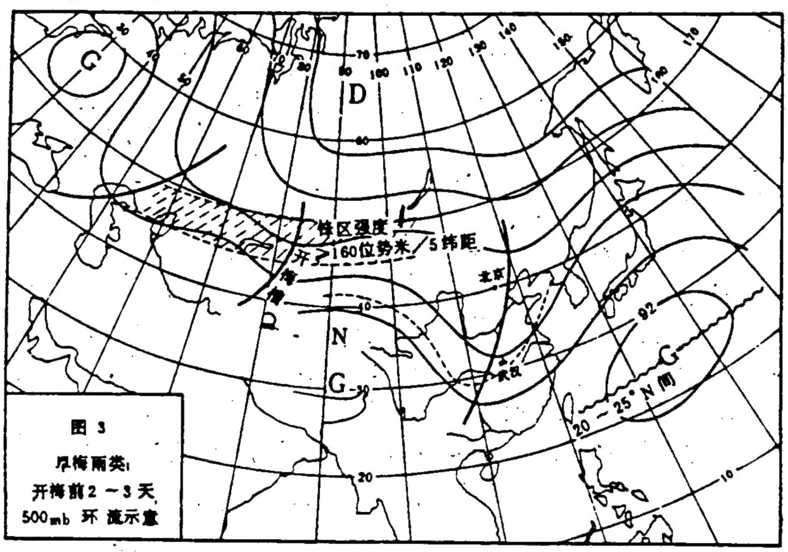


1. Onset of plum rain trough. 2. Cold air moves toward southeast. 3. Frontal zone intensity 160 geopotential meters/5 latitude distances. 4. North of 27° N. 5. Legend. 6. Isobars. 7. Isotach. 8. Sub-tropical high ridge line. 9. Trough. 10. Frontal zone. 11. Path of cold air. 12. Path of warm air. D=low. G-high.

Two or three days prior to the onset of the plum rains (Figure 3) at the eastern portion of the European blocking high at the higher latitudes the cold air moves south, and the area in the middle meridians increases north and south. Along the eastern side of the high plains (East of 105° East) a relatively deep low tough develops, with an altitude differential equal to or less than 20 geopotential meters in the areas of Hankou and Hokkaido. This causes a marked development of a warm ridge in the area of Japan. This warm ridge is on the same phase as the center of the sub-

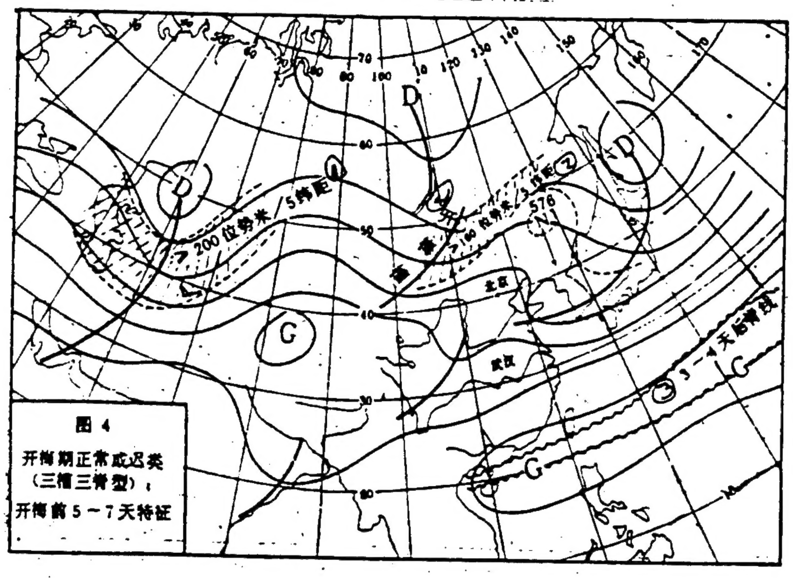
tropical high in the Western Pacific to the south. This causes a marked intensification and northerly movement process in the sub-tropical high. After two or three days, this medium latitude low trough will retreat to the west due to the European blocking high. The cold air in the higher latitudes will no longer bolster the middle latitude areas in China, resulting in the deep through which had been located on the eastern edge of the high plateaus to quickly weaken and move east. The warm ridge behind the trough will combine with sub-tropical high in the Western Pacific at fairly low latitudes, resulting in another marked westerly extension of the coastal sub-tropical high, resulting in further stabilization of the sub-tropical high. Furthermore, the northerly movement and stabilization of the sub-tropical high are necessary conditions for the plum rains to begin. At the same time as this, at the eastern edge of the European blocking high there is also a weak cold air reaching the area of Lake Balkhash, forming a short wave trough. When this short wave trough (onset of plum rain trough) moves east to the river bend area, it causes the onset of the plum rains.

Fig. 3. Model for when the plum rains come early, 500mb circulation two to three days prior to the onset of rains



1. Frontal zone intensity 160 geopotential meters/5 latitude distances. 2. Onset of plum rain trough. D=low. G-high.

Fig. 4. Model for when the plum rains begin on time or are late (three trough, three ridge model) 5-7 days before the onset of the plum rains.



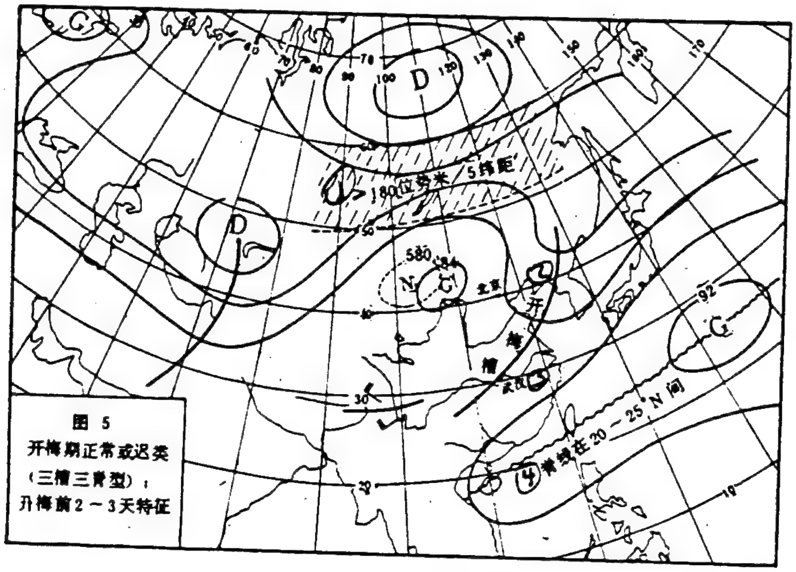
1. ≥200 geopotential meters/5 latitude distances. 2. 160 geopotential meters/5 latitude distances. 3. Ridge line 3-4 days later. 4. onset of plum rain trough. D=low. G=high.

B. The plum rains begin at a normal time or are late. Five to seven days before the plum rains begin, the belt of westerly winds fluctuates back and forth. The subtropical high ridge line in the Western Pacific (same as in category A) has already reached 15° to 20° North. Furthermore, the western ridge of the 588 line has already reached the neighborhood of Hainan Island, and in the middle and last ten days of June it is very easy to satisfy the seasonal conditions for the sub-tropical high ridge line to reach this position. Therefore, in this model, the key to the onset and continuation of the plum rains is whether or not the cold air is able to affect the middle and lower reaches of the Changjiang. Because different positions in the trough ridge distribution from the Black Sea to Japan result in different cold air movements, thus causing different changes in the rain belt. These can generally be divided into the following two situations:

(A). Three troughs, three ridges model. Five to seven days prior to the onset of the plum rains (Figure 4), there is a fairly deep trough in the area of Caspian Sea and the Ural Sea, and ahead of the trough there is a southwest wind of more than 20 meters per second and a frontal zone moving toward the southwest. The intensity of the frontal zone is greater than 200 geopotential meters/5 latitude distances. This causes the warm ridge at the leading edge of this southwesterly frontal zone (eastern edge of Lake Balkhash) to be maintained and the cold air in front of the warm ridge to bolster the low trough to the southwest of Beihu (following this trough is the onset of plum rain trough). At this time there is still a weak high pressure ridge in Northeast China, and a temperature ridge (or warm center) in conjunction with it. This warm ridge will shift to the Sea of Japan and will tend to be in phase with the sub-tropical high in the Pacific to the south, finally causing the sub-tropical high ridge line to generate a northerly movement.

By two to three days prior to the onset of the plum rains, the Northeast warm ridge will have already merged into the sub-tropical high. At this time, because of the resistance of the low pressure zone in the higher latitudes, the warm ridge on the eastern edge of Lake Balkhash will become a wider warm ridge (Figure 5) and a warm center to the northwest of the river bends will work with it. At the same time, the sub-tropical high in the Western Pacific will merge with the northeast ridge as well as with a weak ridge along the East China coast North of 35° North. This facilitates the subtropical high ridge line at the offshore waters West of 140° East to stabilize north of 20° North. While the wide warm ridge in the river bend area continues to move east, the short wave trough ahead of it will combine with the shear which already exists in the high plateau, forming a horizontal trough between the westerly wind belt river bend warm ridge and the sub-tropical high, reflecting in the lower atmosphere as the gradual formation and stability of the plum rain frontal system.

Fig. 5. Model for when the plum rains are on time or late (Three troughs, three ridge model) Two to three days before the onset of plum rains



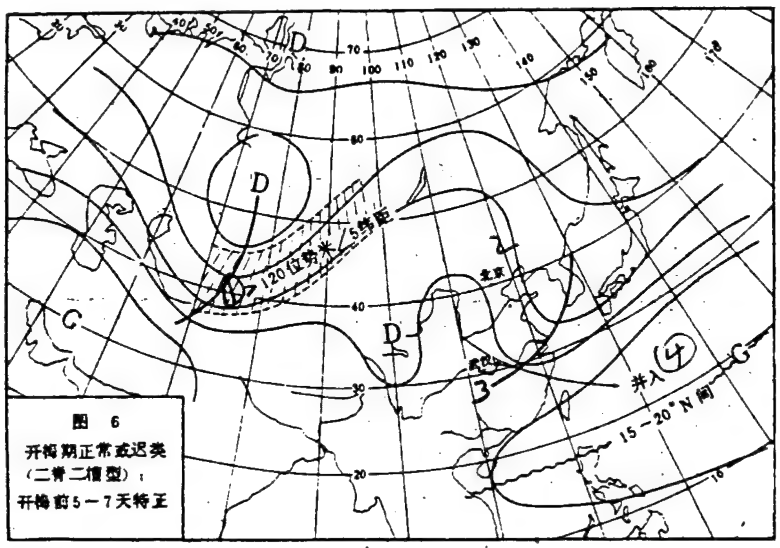
1. ≥ 180 geopotential meters/5 longitude distances. 2. Onset of plum rain trough. 3. Wuhan. 4. Ridge line between 20° and 25° North. D=low. G-high.

(B). Two ridge two rough model: Five to seven days before the onset of the plum rains (Figure 6), the west wind belt trough-ridge distribution locations are exactly opposite that in the previously described model. There is a high pressure ridge at the Caspian Sea, and ahead of this ridge at Lake Balkhash there is a weak pocket of low pressure which is transient. Furthermore, between the river bend area to Beihu is a weak broad warm ridge because of the blocking of a weak high pressure zone in the higher latitudes. This warm ridge will merge into the sub-tropical high in three or four days, and cause the sub-tropical high in the offshore Western Pacific to move sharply to the north.

Two to three days prior to the onset of the plum rains (no figure presented), the high pressure ridge at the Caspian Sea develops and moves to the East. This causes the weak low pocket at

Lake Balkhash to become a transient low trough, and this transient low trough splits into small troughs while passing over Xinjiang and Gansu. When these short wave troughs move east of the river bend area and encounter the southwest flow of air moving around the sub-tropical high, the plum rain frontal system gradually develops in the lower atmosphere.

Fig. 6. Model for when the plum rains are on time or late (two ridge two trough model) five to seven days prior to the onset of the plum rains



1. ≥ 120 geopotential meters/5 latitude distances. 2. Beijing. 3. Wuhan. 4. Merge into. D-low. G-high.

In summary, there is a great difference in the Euro-Asian circulation forms when the plum rains begin early and when then begin on time or are late. During years when the plum rains began early, which was just at the change of seasons between the end of Spring and the beginning of Summer, the westerly wind circulation form is still similar to the spring Euro-asian blockage stable pattern. The west wind stream tends toward the south, and the cold air easily reaches south to the middle and lower reaches of the Changjiang. At this time, if the sub-tropical high average ridge line location can reach somewhere around 20° North and stabilize,

then it is possible to have the surface frontal zone and the rain zone be maintained on either side of the middle and lower reaches of the Changjiang. When the plum rains begin on time or late, the circulation form is that the circulation in the middle and higher latitudes of Europe and Asia are in a state of "disorder", that is there are a number of small troughs and small ridges. At this time, as the seasons are delayed, the sub-tropical high ridge line locations can generally easily reach 20° North, and the key is whether the form of the north wind belt circulation is advantageous to having cold air move south to the area of the middle and lower reaches of the Changjiang. Therefore, we believe that forecasting for early plum rains should emphasize the movement and changes in the sub-tropical highs, and forecasting for on time or late plum rains should emphasize the adjustment and movement of the short wave troughs and spines of the west wind belt.

The points to focus on in the 500mb circulation form in mid-range forecasting of the onset of the plum rains are:

a. The sub-tropical high in the Western Pacific makes at least one sharp move to the north before the onset of the plum rains, and the sub-tropical high northerly move is signalled by the passing of a warm air ridge over the river bend area which merges into the sub-tropical high, or there is a warm ridge in the Sea of Japan which overlays the northern edge of the center of the sub-tropical high, and causes the sub-tropical high to make a sharp move to the north.

b. Note the formation of stable long wave ridges and blocking highs in central Europe and the middle and higher latitudes of Asia. Under these conditions, the lower reaches of these ridges often have high pressure ridges north of Japan which are of the same phase as sub-tropical highs in subtropical areas of the Western Pacific and cause the sub-tropical highs to move north.

c. The circulation of the Asian west wind belt in the middle latitudes tends to be flat or to be increased numbers of short waves troughs and ridges. Following this, large troughs will no longer appear over the coastal waters of Southeast Asia (trough bottom will not exceed 30° North), or else the sub-tropical high will not be able to stabilized at a northerly position.

d. Note the appearance of the short wave troughs which bring about the onset of the rainy season (also refers to cold air). In most years, this type of short wave trough moves east from Xinjiang to the Hexi Corridor. In a few wears it moves southeast from Beihu.

2. Characteristics of the 500mb circulation and surface conditions at the onset of the plum rains

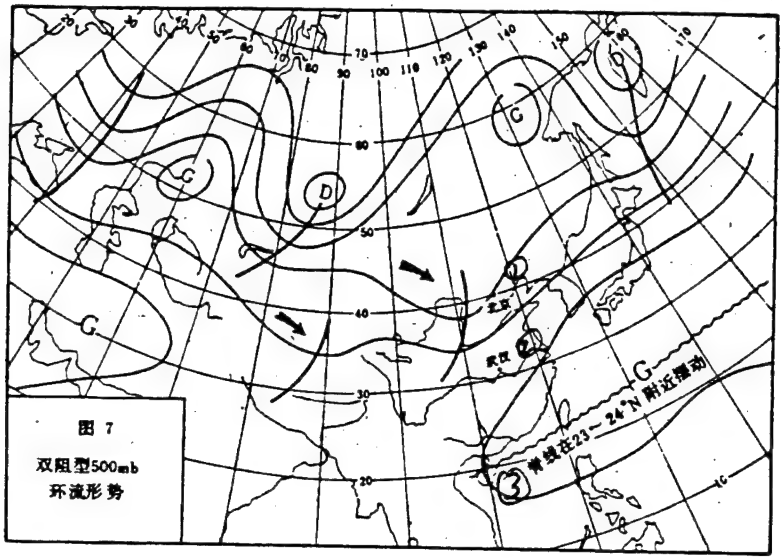
In actual forecasting operations, in order to more easily determine the characteristics of the circulation patterns at the onset of the rainy season, we analyzed and summarized the 500 mb and surface circulation patterns the day before and the actual day the plum rains began. The results are as follow:

A. Characteristics of 500 mb circulation at the onset of the plum rains

When the rainy season begins, several major positions and actions in the sub-tropical regions are relatively consistent and steady. These are the mostly elongated distribution of high pressures in the Northwest Pacific, and their ridge line (from southern Japan to the South china Sea) tends to incline toward the southwest. The average ridge line position between 125° and 140° East moves from south of 18° North where it was two or three days ago to the north between 19° and 24° North. At the same time, the western ridge point of the sub-tropical high perimeter 588 characteristic line has already extended to the vicinity of Hainan

Island (if there had been a high in the South China Seas, by this time it has disappeared or merged into the Western Pacific Subtropical high). Also, in Eastern India or the Bay of Bengal there is often a stable low pressure trough, forming a pattern of a high to the east and low to the west, more than 20 geopotential meters higher over the major islands of Japan that at Lhasa. This ensures a mostly southwest air flow over large reaches south of the Changjiang which helps to maintain the frontal zone of the middle and lower reaches of the Changjiang and bring moist air.

Fig. 7. 500mb circulation pattern in the dual blocking model\



1. Beijing. 2. Wuhan. 3. Ridge line fluctuating between 23° and 24° North. D=low. G=high.

As for the west wind belt, except for an nondeveloping short wave trough between the river bend area and the Korean Peninsula (this trough is the one that forms the onset of the rainy season, and we call it the onset of the plum rain trough), the middle and higher latitudes long wave troughs (or blocking highs) come in many forms, and can basically be divided into three categories.

The first category is a dual resistance model (Figure 7). The primary characteristic of this model is that there is often two stable high pressure systems (high ridges) between 50° and 70°

North. The western resistance is near the Urals and the Eastern resistance is in the area of Yakutsk, and there is a low pressure trough running between the two and a flat west wind circulating between 35° and 45° North. At this time the average ridge line of the sub-tropical high in the Western Pacific lies approximately between 23° and 24° North. The cold air channel to maintain the plum rain frontal system branches off from the main channel east of lake Balkhash and comes south down the Hexi Corridor. Another branch moves over from east of the high plateaus.

The second category is a three resistance model (no figure provided). The primary characteristics of this model is that the area between 50° and 70° North is one of frequent resistant high activity, and there are frequently three stable resistance highs (or high pressure ridges). The east resistance is located in the Yakutsk area. The western resistance is located in Central Europe, and the middle resistance is located around Lake Beijia'er (phonetic). There is a flat westerly wind flow in the Asian regions south of the resistance highs (35° to 45° North). Within this flat westerly wind flow there are short wave troughs constantly being generated and shifting east. They do not further develop, however. The average ridge line of the sub-tropical highs in the Western Pacific generally fluctuate around 23° North. At this time the source of the cold air is: a branch off from the cold trough around Lake Balkhash, and the other moving south from the eastern edge of Lake Beijia'er. When the short wave troughs which have split off move east over the river bend area, they often take the place of the onset of plum rain trough. In this way they promote maintaining and stabilizing the plum rain frontal system in the areas of the middle and lower reaches of the Changjiang.

The third category is a single resistance model (no figure is provided). The primary characteristics of this model is that between 50° to 70° there is only one stable high (or high ridge) located north of Lake Beijia'er (phonetic). During a number of

years there is also a shear low pocket in the area of Lake Balkhash. At the same time, the tail end of the low trough maintained in Northeast China can extend south to the Changjiang and Huai Rivers. At this time the primary source of cold air is south along the northeast low trough from East of Lake Beijia'er (phonetic). However, because the average high ridge line along the coast of East China has already moved fairly far north (in most years fluctuating around (25° North), although the plum rains frontal system formed is somewhat to the north, it can still be maintained in the areas of the middle and lower reaches of the Changjiang.

Generally speaking, these upper atmosphere circulation forms belong to the (stable plum rain models", but it must be point out that during the periods of plum rains these three types of west wind flow models will commonly shift back and forth, especially during years when the plum rains are maintained over a longer period of time. However, during most years, following the rainy season one west wind flow model can easily occur, and is appropriately named the "standard model".

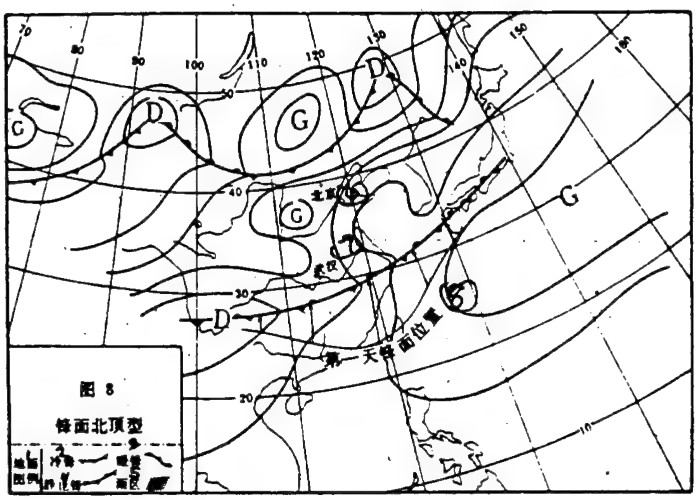
B. Surface weather characteristics at the onset of the plum rains

Looking at the distribution of primary weather systems on a map of East Asia, the common points are that the areas south of the Huanghe form a high to the east and a low to the west, that is, the vast waters of the western Pacific is a stable high zone, and during most years its high pressure dam extends to the East Asian coastal waters. In West China areas the pressure is lower than in Shanghai, and the sea level pressure distribution is characteristically Luerdao>Shanghai>Chengdu. At the same time, between 40° and 45° North in North and West China regions there is a frontal system, behind the front the primary cold high pressure is in the area of Bahu Lake, and during most years the intensity at the center of the cold high is less than 1020 mb. However, when

the rainy season begins, because of the different evolutionary formation processes of the "plum rain frontal system" in the Changjiang areas, there result three different situations:

The first model is where the front protrudes to the north. The frontal system is originally in the areas south of the Changjiang, but because the high altitude Sub-tropical high moves north and the northern cold air retreats, causing the rainy season frontal south move from south of Nanling to protrude north of Nanling and sit over the middle and lower reaches of he Changjiang. In most years the rainy season is then over for the areas south of the Changjiang. In some years, because of new cold air coming in, it is possible that the front moves back south, but does not stay south of the Changjiang for very long, as in 1964 (see Figure 8).

Fig. 8. Model of frontal system protruding north

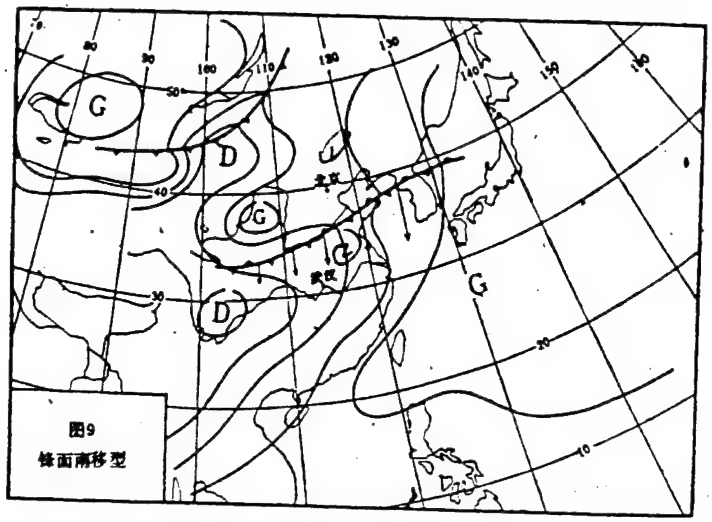


1. Legend. 2. Cold front. 3. Warm front. 4. Stationary front. 5. Rain. 6. Beijing. 7. Wuhan. 8. Position of front on first day.

The second model is where the front moves south. The rainy season front south of the Changjiang has already dissipated and but there is a stationary front between the Huanghe and the Huai River. However, because additional cold air moves south from the China-

Mongolian border, it causes the stationary front between the Huanghe and the Huai River to move down to the Areas of the Changjiang and Huai River, and to stabilize there, forming a plum rain frontal system as in 1966 (see Figure 9).

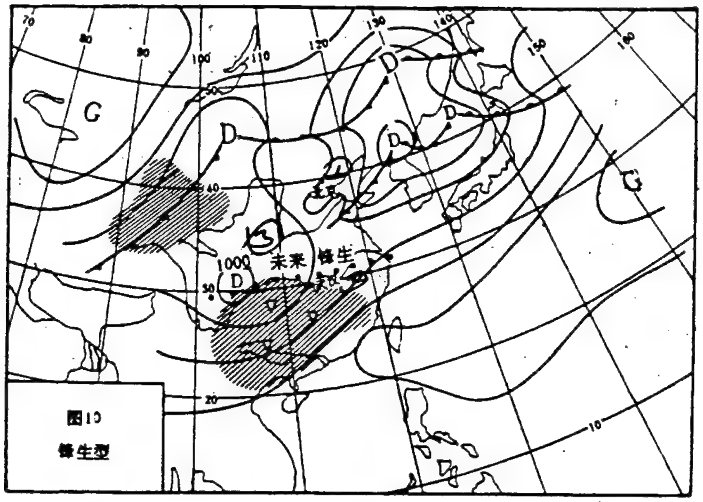
Fig. 9. Model of frontal system moving south



1. Beijing. 2. Wuhan

The third model is where the frontal system is generated in the regions of the Changjiang. The characteristics of this model is that the rain season frontal system has already dissipated south of the Changjiang, and there is a low pressure system in the Northeast which has already penetrated the low. At this time, because the high altitude sub-tropical high has protruded north and shear lines have been formed on the 700 mb map, causing occasional rainfall to be generated in the warm regions in the middle and lower reaches of the Changjiang, and later west of the river bend area cold air expands south, causing a more and more pronounced frontal system to be generated in the areas of the middle and lower reaches of the Changjiang as at the onset of the rainy season in 1972 (see figure 10).

Fig. 10. Model of frontal system generated



1. Beijing. 2. Wuhan. 3. Future front generation.

In summary, when considering the question of establishing a "plum rain frontal system" in the surface atmospheric pressure field", except for the first model, in the second and third model special attention should be paid to the dissipation of the existing surface frontal system of the rainy season south of the Changjiang.

3. Mid-range forecasting for heavy to torrential rains during the plum rains

April to July of each year (before the conclusion of the plum rains) is a season of much heavy to torrential rain (daily rainfall greater than 30cm) for the Shanghai area. We did a study of 22 occasions of heavy to torrential rain during 28 months in the years 1964 to 1972. We analyzed that the meteorological processes causing heavy to torrential rainfall in Shanghai were generated against the background of certain large circulation pattern and is connected to the areas of seasonal cold and warm air flows and the variations in the intensity of these air flows. At the same time, it is also related to changes in major factors at the

meteorological stations. Following the operations described above, we selected a number of characteristic regions, and major factors at characteristic stations and our station as well as changes in these for the upper and lower reaches in the Shanghai area on a 500 mb map and a 700 mb map to serve as forecasting factors.

In order to express the movement of warm air, we selected quantitative changes in major factors at number of meteorological measuring stations along the northern and eastern edge of the high plateaus or characteristic regions to serve as forecasting factors such as the 500mb 24 hour positive temperature variation, 500mb and 700mb low pocket central intensity and low pocket location at Station 777 and Station 888 in Region 51 (hereafter refereed to as warm zone I) and Station 889 in Region 52 and Station 463 in Region 53 (hereafter refereed to as warm zone II) and the altitude variation between the 500 mb altitude at the Global East 47 Region 945 Station and Southwest China's 57 Region 029 Station, as well as the altitude of the 500 mb and changes in the altitude at the Shanghai station and the latitude of the 584 line at 120° East.

In order to express the cold air movement, we selected the 500 mb 24 hour negative temperature variation at the Region 36 Station 177 and Region 35 Station 796 near Lake Balkhash (hereafter referred to as cold zone I) and Stations 710 and 354 from Lake Beijia'er (phonetic) to Mongolia (hereafter referred to as cold zone (() to determine the movement of cold air (no figure presented).

However, in actual forecasting operations, one is often faced with the following problem: the circulation patterns resulting in heavy to torrential rainfall at our station are not always the same. At the same time the various forecasting factors do not always play the same role in the process of each large to torrential rainfall (that is, at times a certain factor plays a greater role, and another factor plays a smaller role). Therefore,

we generally approximated weather systems (positions of troughs and ridges) and achieved another certain critical value in the changes of major factors of certain characteristic regions and characteristic points which serve as initiating conditions and categorized them. In this manner we both were able to reflect the characteristics of weather conditions and were also able to avoid generating subjective factors when evaluating the starting place of patterns.

Through categorizing, we eliminated those days which did not meet the conditions of circulation model and critical value (characteristic region, etc), and in this manner, out of the data for 28 months, only 69 examples remained, those which could produce heavy to torrential rainfall. These 69 samples were divided into four models. There were 29 occurrences of the first model, eight of the second model, ten of the third model and 22 of the fourth model. Then we calculated each model using the successive regression method and established a formula for forecasting. In establishing the formula, we first made a qualitative determination (that is, whether or not there was heavy to torrential rainfall), and when there was qualitative determination that there was heavy to torrential rainfall, we made a forecast of how much and what time. Looking at the calculated results of these 69 samples which fit the models, there were heavy to torrential rains on 22 occasions, and another 21 occasions fit the model fairly well, which were qualitatively fairly good, but quantitative fairly poor.

In order to save space, below we will only use one model for illustration, which will be Model 1.

MODEL ONE.

1. Characteristics of the 500mb circulation patterns

Model a: The characteristics of this category are that the Sub-tropical high is stretched out in an east-west direction, with the ridge line between 20° and 25° North. The center intensity can reach 592 to 596 geopotential meters, and the cold air comes down south from Lake Beijia'er (phonetic) across the river bend area, causing the sub-tropical high over the Southeast coastal regions to retreat to the south. Then the ridge of warm air over the high plains moves east and merges with the sub-tropical high, forming a east high west low pattern.

Model b: The characteristics of this category are that the warm ridge in the river bend areas first merges into the sub-tropical high, and then there is a blast of very clod air which moves south from lake Balkhash, and combines with the low trough in the Qinghai and Tibet regions and moves east.

2. Initial conditions: Anytime five of the nine conditions mentioned below, it is possible to use the equation in this model for calculations.

Conditions: (1). The 584 line on the 500mb map at 120° East lies on a latitude of 28° North or higher. (2). The altitude on the 500 mb map of the Region 47 Station 945 minus that of the Region 56 Station 029 is greater than seven geopotential meters. (3). On the 500 mb map the Region 47 Station 945 altitude value is greater than 588 geopotential meters. (4). On the Shanghai 500 mb map the elevation value is 581 geopotential meters. (5). On the shanghai 500 mb map there has been a change of more than four geopotential meters over the last 24 hours. (6). In cold zone I and cold zone II if only one station has a 500 mb negative change in temperature of $\leq$-6°C, it serves to meet starting area conditions. If this is achieved in both cold zones, then calculations can be done with two starting areas. (7). In Warm zone I or warm zone II if only one station has a positive temperature change of $\geq$4°C (in April, $\geq$5°C) within 24 hours, then

it serves as achieving initial conditions. If this is achieved in both warm zones, then calculations are made for two initial conditions.

3. The forecasting equation

Equation 1. (Constant y_1) - forecasting no heavy or torrential rains.

If there will be heavy to torrential rains

there will not be torrential rains

$$y_1=0.429 - 0.96x_5 + 0.021x_6 + 0.017x_9$$

Equation 2. (Constant y_2) - forecasting heavy to torrential rains.

$$y_2=13.818 - 5.276x_5 + 3.969x_7 + 1.1085x_8 + 1.132x_9$$

Equation 3. (Constant y_3) - forecasting which day will see heavy to torrential rains

$$y_3=4.364 - 0.278x_3 + 0.421x_5 + 0.299x_7 + 0.010x_9$$

In the equations above, the meaning of the factors are:

x_3 is the elevation value at Region 47 Station 945 minus the elevation value at Region 56 Station 029.

x_5 is the maximum value of ΔT_{24} in warm zones I and II.

x_7 is the positive change in 500mb altitude value over 24 hours at Shanghai.

x_8 is daily high temperature (T_G) in Shanghai. When T_g29°C or $\leq$19.0C, it is treated as zero. For values between 19.1° and 29.0C, calculations are done using actual values.

x_9 is the 14 hour absolute humidity (e_{14}) for shanghai, when $e_{14} \geq 28$mb or ≤ 16mb, it is always treated as zero. For values between 16.1 and 27.9mb, calculations are done using actual values.

Between April and July during the years 1973 to 1976 (before plum rains ended), these equations would be effective to a certain degree in qualitative forecasting of heavy to torrential rain in actual forecasting operations. However, they were somewhat lacking quantitatively and for times.

Also, at times the calculation results were that there would be heavy to torrential rains, but these occurred in individual districts in the cities, but not at the observation sites. This problem of individual points and overall areas will require further improvement in future work. As for qualitative forecasting, a number of heavy rains have not been forecast, primarily because the model of heavy to torrential rains caused by cold air along an eastern path has not yet been included.

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